THE HOME RANGE OF ELEPHANTS AND ITS IMPLICATIONS FOR MANAGEMENT OF THE MUDUMALAI WILDLIFE SANCTUARY, TAMIL NADU[1]

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(With four text-figures)

Introduction

The home range of elephants has been extensively studied in Africa, covering habitats ranging from deserts (Viljoen 1989) to tropical forests (Merz 1986). In Asia, home range has been studied in the Malaysian rain forest (Olivier 1978) and deciduous forests in south India (Sukumar 1985 and present study). Home range sizes vary depending on the habitat types. In Africa, home range sizes of 14 to 52 sq. km were reported for Manyara (Douglas-Hamilton 1972 as cited by Viljoen 1989) and 1763 to 2944 sq. km for the northern Namib Desert region of Kaokoveld (Viljoen 1989). In Asia, home range sizes varied from 32.4 to 166.9 sq. km for the rain forests in Malaysia (Olivier 1978); in south India from 105 and 115 sq. km for clans and 170 to 320 sq. km for adult bulls in deciduous forests (Sukumar 1989) and 124.3 sq. km and 156 sq. km for two female groups in primary and secondary evergreen forests (Easa 1988).

Though there have been many studies on home ranges, few have attempted to develop specific recommendations for managers. In this paper the data on elephant movements collected during the project on the ecology of the Asian elephant *Elephas maximus* in the Mudumalai Sanctuary in Tamil Nadu are being used to develop management recommendations for the study population. While this is mainly aimed at the managers of the Mudumalai Wildlife Sanctuary and the adjoining areas in Tamil Nadu, Karnataka and Kerala, the recommendations might also prove relevant to other areas in India.

Study Area

The Mudumalai Wildlife Sanctuary (W.S.) is located between 11°30' and 11°39'N and 76°27' and 76°43' E, in the Nilgiris district, Tamil Nadu. The sanctuary covers an area of 321 sq km and lies at the tri-junction of three states, Tamil Nadu, Karnataka and Kerala. To the north of Mudumalai W.S. lies Bandipur Tiger Reserve and to the west the Wynnad W.S. To the east and south are Revenue Lands (private agriculture and estate lands, privately owned forests and forested land under the control of the Revenue Dept.) and Reserve Forests (Fig. 1).
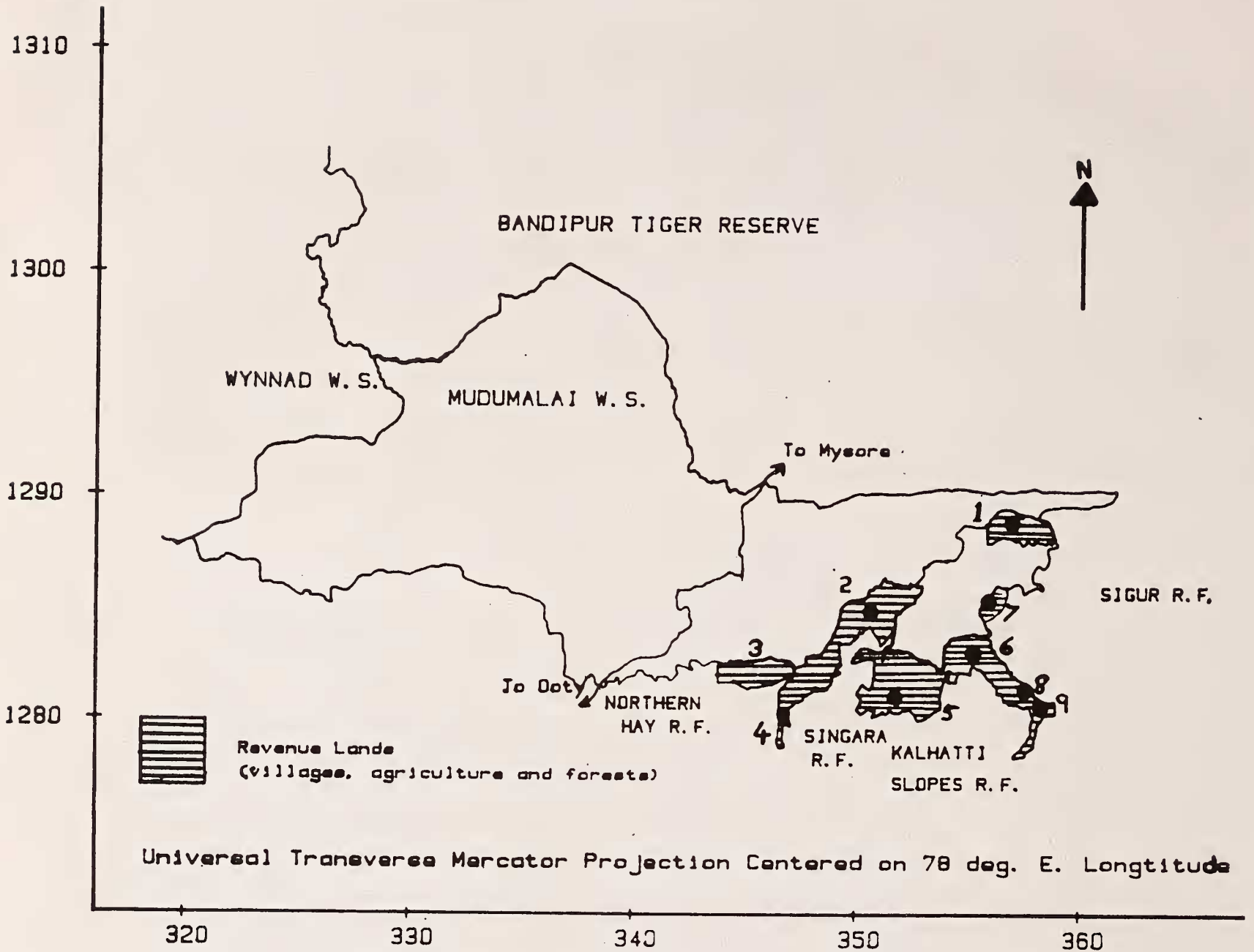
Fig. 1. Map of study area showing the locations mentioned in the text. Numbers indicate the following places:
  1. Moyar, 2. Masinagudi, 3. Northern Hay Estate, 4. Singara, 5. Mavinhalla, 6. Mavinhalla, 7. Chemmanattam, 8. Chadapatti, 9. Valatottam.

Mudumalai W.S. is a part of a complex of four sanctuaries, the others being Bandipur Tiger Reserve, Nagerhole National Park (both in Karnataka) and Wynnad W.S. (Kerala). These four areas and the adjoining Reserve Forests cover over 3300 sq.km of forest and support a population of 1800 to 2300 elephants (based on Forest Dept. census figures). Together they form one of the largest single protected elephant population and elephant range in Asia. This is one of the best areas for long term conservation of elephants in Asia.

The terrain is undulating, with an average elevation of 1000 m. It is drained mainly by the Moyar river with its several tributaries of smaller rivers and streams. The western part of the sanctuary is characterised by the frequent occurrence of *vayals* (swamps) at the foot of hills. Undulating terrain with poor drainage has been responsible for the formation of these *vayals*.

The rainfall varies from 600 mm to 2000 mm, with the eastern areas getting the least rainfall and the western part of the sanctuary the highest. Correspondingly, the vegetation varies from Thorn Forests in the east to Semi-

evergreen Forest in the west. The main vegeta-
tion types are Moist Deciduous, Dry Deciduous
Forests and Thorn Forests (for details see Daniel
et al. 1985).

OBJECTIVES OF THE STUDY

The study tried to find answers to the follow-
ing questions, which would be important to the
proper management of elephants in the study area.

1. The size of home range for clans and
adult males in the study area.

2. Whether the home ranges of clans and
adult males were confined only to protected
areas (National Parks and Wildlife Sanctuaries)
or whether they extended into areas where the
home range and the habitat within, were ex-
posed to lower protection levels. It is assumed
that a protected population can be so named
only if the study animals, their home range and
the habitat within it, are protected.

3. The threats to the habitat within the
home ranges of the study population both in
terms of actual area loss and indirectly through
habitat degradation.

4. The bottlenecks in the movement cor-
ridor to the Eastern Ghats.

5. The effects of the loss of threatened
areas within the home ranges on the study
population.

6. The possible effect of the loss of habitat
in relation to the man-elephant conflict.

7. The methods of evaluation of areas that
are critically important to the study population,
and the management requirement for protection
of these areas from loss (direct or through
degradation).

MATERIAL AND METHODS

The study was conducted in the Mudumalai
W.S. Adjoining areas in Tamil Nadu (Sigur
Range and Revenue Forests) and Karnataka
(Bandipur National Park) were also covered to a
lesser extent. Movement patterns and home ran-
ges of elephants were determined through visual
sightings of individually identified elephants.

Elephants were recognised by characteristics
such as cuts and holes in the ears, shape of the
tusks and hair patterns of the tail (Douglas-
Hamilton and Douglas-Hamilton 1975, Moss
1988). The study animals were photographed
and could be clearly identified. In this paper, the
movement patterns of three clans (codes LBF,
RDC and HCF) and three adult males (codes
CT, TPSR and RSB) have been used. A clan is
defined as a group of elephants believed to be
related, which showed coordinated movement
(Moss 1988).

The elephant locations were analysed using
the computer programme SEAS (Spatial Ecol-
ogy Analysis System) developed by John Carey,
University of Wisconsin, Madison, Wisconsin,
U.S.A. Home ranges were calculated using min-
imum convex polygon method (Mohr 1947).
Data were collected from June 1985 to Decem-
ber 1990 for all individuals except one bull (CT)
which was shot in December 1986. For the pur-
pose of evaluating administrative and manage-
ment problems created by the study animals'
ranging behaviour, the following four ad-
ministrative areas were considered.

National Park (N.P): An area designated for
wildlife conservation, with a higher protection
status than a wildlife sanctuary. Under the con-
trol of the Forest Department (Wildlife Depart-
ment).

Wildlife Sanctuary (W.S.): An area designated
for wildlife conservation. Under the control of
the Forest Department (Wildlife Department).

Reserve Forests (R.F.): These areas are under
the control of the Forest Dept., but not Wildlife
Dept. Open to normal forestry operations and
not legally designated as areas for wildlife con-
servation.

Revenue Land: Includes both forested land
under private ownership and land under the con-
trol of the Revenue Department.

The extent to which home ranges of the
study population overlapped different
administrative areas was calculated using the
SEAS programme.

RESULTS

The home range areas ranged from 111.2 to 265.6 sq. km ($\overline{X}$ = 203.4 ± 51.7 sq. km; Table 1). Fig. 2 shows home ranges of the three clans and Fig. 3 the home ranges of three adult males. The greatest linear dimension of the home ranges are given in Table 1. With the exception of clan HCF all showed a general north-west/south-east direction along this axis. In terms of size the home ranges of the females were larger than those earlier reported (Easa 1988, Olivier 1978, Sukumar 1989). Even in the present study the home range of clan HCF has not been well defined and hence appears smaller than that of the other two clans. The home ranges of the other two clans (LBF and RDC) are likely to represent their real size in the study area.

The home range of adult male CT was well defined as this male was very easy to identify by its tusks. Though data were collected over only a short period its home range size is large. Home range sizes for males also can be taken to represent their minimum sizes required for these animals.

It can be seen from Figs. 2 and 3 that most of the home ranges extend beyond the boundary of Mudumalai W.S. The extent to which home ranges extend into different administrative areas are given in Table 2. For the study animals, the percentage of their home range extending into Reserve forests ranged from 0% to 13.4% ($\overline{X}$ = 6.8% ± 4.8%), and in the case of Revenue Lands (forest) from 0% to 14.2% ($\overline{X}$ = 8.7% ± 4.8%). In addition all the study animals ranged into Bandipur N.P. (range 3.2% to 59%) and one clan (LBF) had 6.4% of its home range in Wynnad W.S. With the exception of clan RDC all other study animals ranged outside the protected areas. The home ranges of all (except clan RDC) are exposed to the threat of habitat loss. Only one study clan, RDC, can be said to be fully protected. Other clans and adult males have only a part of their home ranges within protected areas.

There are no bottlenecks or threatened corridors between Mudumalai W.S. and the two adjoining protected areas. Bandipur N.P. and Wynnad W.S.

The most important factor is that the elephant population of Nagerhole N.P., Bandipur Tiger Reserve (N.P.), Wynnad W.S. and Mudumalai W.S. have a link to the Eastern Ghats population through Sigur R.F. There are elephants resident in Sigur R.F. on the eastern boundary of Mudumalai W.S. These range into Mudumalai W.S. mainly during the wet season and in the dry season they move into the Moyar valley. Sukumar (1989) has also recorded elephants from the Eastern Ghats moving into Moyar valley during the dry season. It is here

TABLE 1

SUMMARY OF DATA AND HOME RANGE SIZE OF FIVE ELEPHANTS IN MUDUMALAI W.S. FOR THE PERIOD 1985/86 TO 1990/91

| Elephant identification	Period of observation (months)	Home range size (sq.km)	GLD	Direction along GLD	No.of records (n)	Unit
LBF	69.0	232.0	36.7	313°/133°	257	Clan
HCF	60.5	111.2	15.0	252°/ 72°	60	Clan
RDC	56.5	265.6	21.7	286°/106°	56	Clan
RSB	65.5	199.7	24.8	296°/116°	209	Adult male
CT	18.5	243.4	30.5	285°/105°	103	Adult male
TPSR	51.3	168.2	19.9	297°/117°	53	Adult male

GLD = Greatest linear dimension of home range.
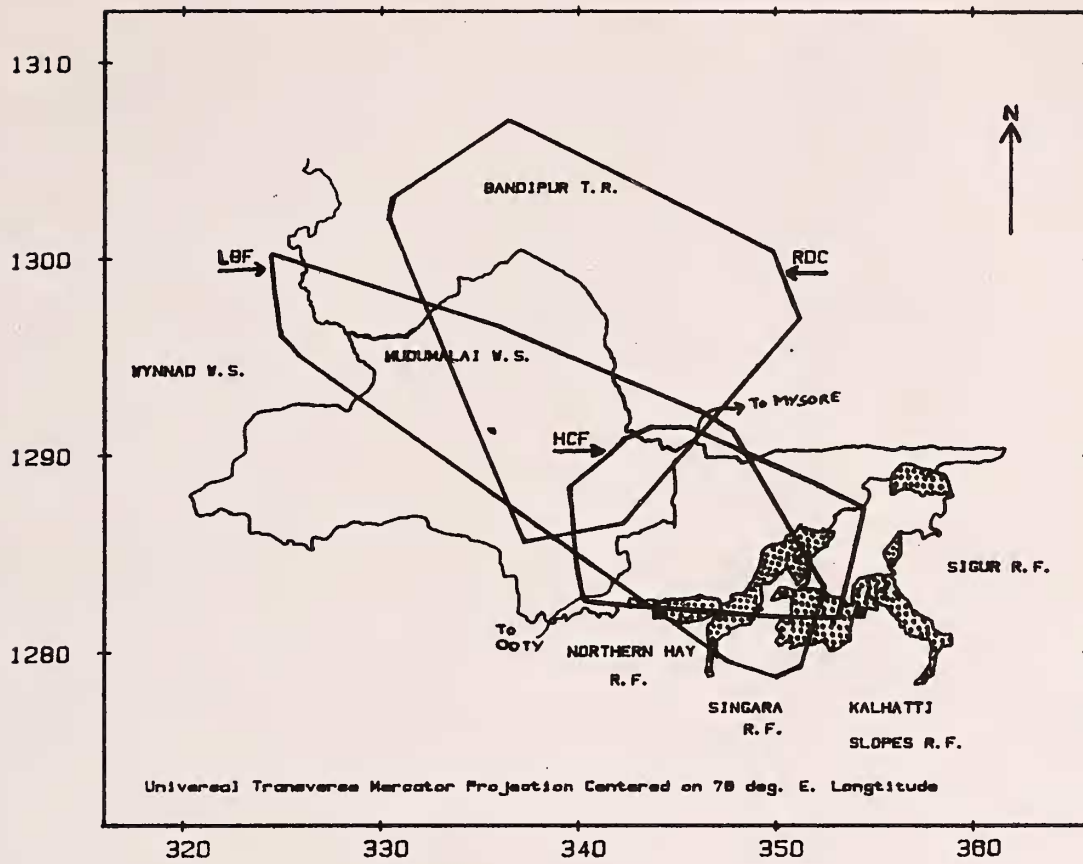
Fig. 2. Home range of three clans (LBF, RDC and HCF).
Stippled area indicates Revenue Lands (includes villages, agriculture and forests).
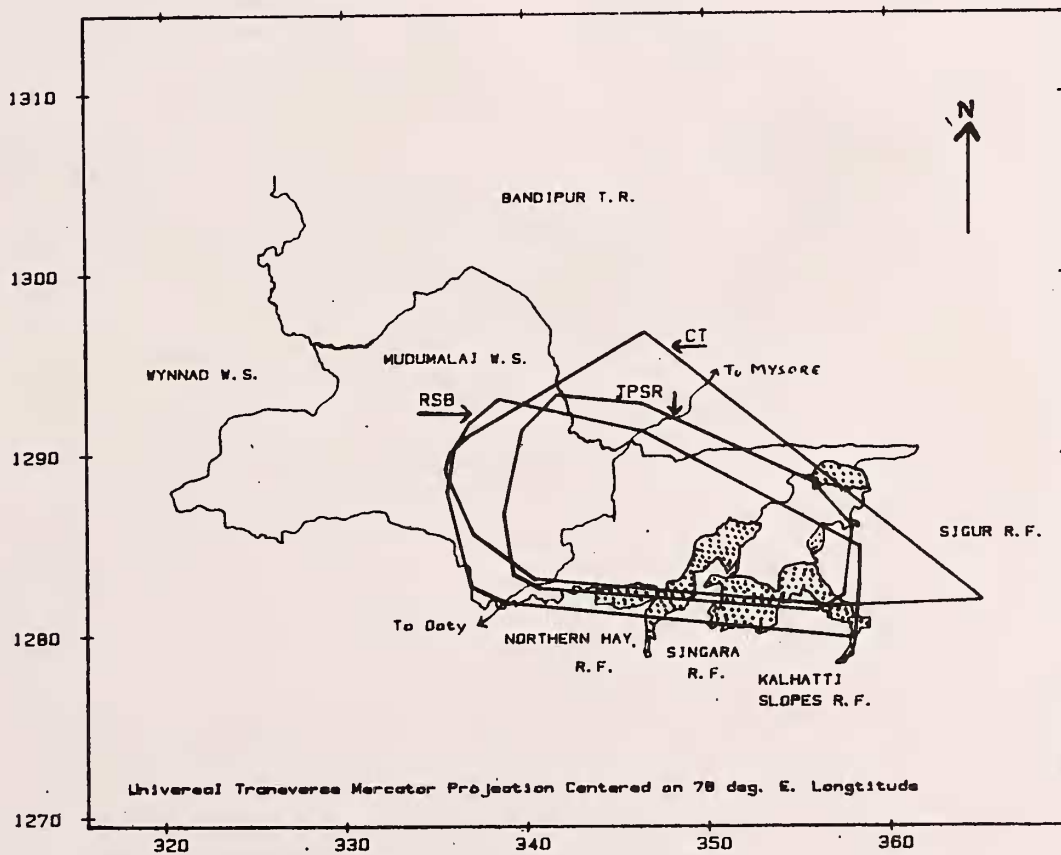

Fig. 3. Home range of three adult males (CT, RSB and TPSR). Stippled area indicates Revenue Lands (includes villages, agriculture and forests).

TABLE 2

PERCENT OF HOME RANGES LYING WITHIN DIFFERENT ADMINISTRATIVE AREAS

Identification	Mudumalai W.S.*	Bandipur N.P.**	Wynnad W.S.***	Reserve Forests*	Revenue Land*
LBF	69.3	11.6	6.4	4.6	7.0
HCF	79.8	3.8		3.5	12.9
RDC	41.0	59.0	—	—	
RSB	70.3	3.2	—	12.3	14.2
CT	59.4	20.2	—	13.4	7.0
TPSR	71.0	10.8	—	7.0	11.2

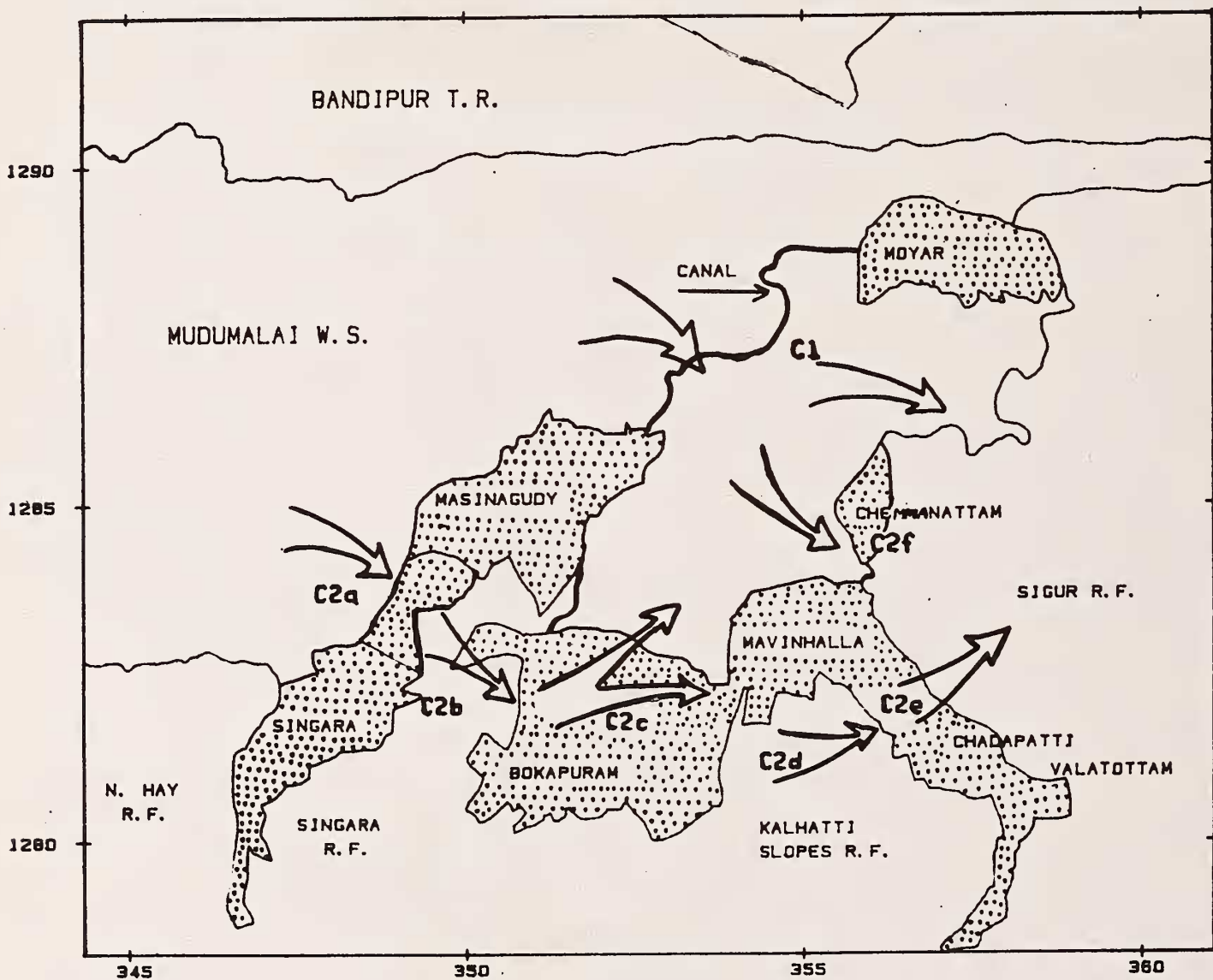*=Tamil Nadu　　**=Karnataka　　***=Kerala

Fig. 4. Corridors between Mudumalai W.S. and Sigur R.F. Arrows indicate routes used by elephants to move into Sigur R.F. They also move back into Mudumalai W.S. along the same routes. Alphanumeric code represent the following corridor areas. C1. Canal between Masinagudi and Moyar villages, C2a. Singara estate land (forested) between Masinagudi and Singara villages, C2b. Singara R.F. C2c. Revenue land between Bokkapuram village and Mudumalai W.S., C2d. Kalhatti Slopes R.F., C2e. Revenue land between Mavinhalla and Chadapatti villages, C2f. Revenue land between Mavinhalla and Chemmanattam villages.

that the elephants from the Western Ghats and Eastern Ghats mix. Thus the main corridor between the Western Ghats and Eastern Ghats is the Sigur R.F. on the Western Ghats side.

There are two routes (corridors) between Mudumalai W.S. and Sigur R.F. (Fig. 4). The first route is between Moyar and Masinagudi villages. This area lies entirely within the Mudumalai W.S. There is a canal running between the two villages (C1 in Fig. 4) and at present elephants can easily cross it.

On the other route there are a series of corridors forming a narrow strip running along the base of the Nilgiri mountains.

(a) The most crucial one is between Masinagudi and Singara villages. This is a very narrow strip of forest land owned by the Singara Estate (C2a in Fig. 4).

(b) From the Singara estate land (C2a) the elephants can move into Singara R.F. This R.F. also acts as a corridor (C2b in Fig. 4).

(c) From Singara R.F. they can move either into the sanctuary or through the Revenue Land (forested) north of Bokkapuram village. These revenue lands act as yet another corridor (C2c in Fig. 4).

(d) The elephants can move further east into the Kalhatti Slopes R.F. (C2d in Fig. 4).

(e) The Revenue Lands (forested) between Mavinhalla and Chadapatti villages form the last corridor between Kalhatti Slopes R.F. and Sigur R.F. (C2e in Fig. 4).

(f) Another corridor exists between Mavinhalla and Chemmanattam villages. This again is Revenue Land. At places where there is direct connection between the Sanctuary and Reserve Forest, the fencing of the Nehru Ecological Park acts as a barrier (C2f in Fig. 4).

DISCUSSION

The size of the home ranges indicates that large areas are required to support elephants in the study area. At present the complex of protected areas (Nagerhole N.P., Bandipur N.P., Mudumalai W.S. and Wynnad W.S.) is large

enough to support several clans. But even now there are clans within these protected areas which range outside and are not in the true sense fully protected, i.e. a part of their range can be lost.

The loss of area could be through direct loss (conversion to non-forest use or by fencing off) or indirectly through habitat degradation (cattle grazing and other human activities). If such a loss were to occur the Revenue Lands (forested) would be the first to go. These together constitute 7% to 14.2% of the study animals' home ranges (except for clan RDC, which does not use these areas). The best way of assuring the long term survival of these threatened habitats is to convert them into Sanctuaries or National Parks, where feasible.

Though the four protected areas together hold a large elephant population the Minimum Viable Population (MVP) estimated for the area in an earlier study was below 500 (Daniel *et al.* 1987). This was due to selective poaching of males till the mid 1980s. The low male numbers effectively bring down the MVP. This problem can be offset by having a genetic link with another population. The study population has a link with the Eastern Ghats population, through a corridor through the Sigur RF. However, there are several bottlenecks in this corridor. These need to be specially protected. The bottlenecks between Mudumalai W.S. and the Sigur R.F. have been outlined in the results section and are shown in Fig. 4.

In addition to their role as corridors these areas also allow free movement to elephants during their seasonal wanderings. If these areas are lost then the elephants will get boxed into patches of forest and could cause considerable damage to crops, property and human lives. Even if they are not boxed into specific areas they will have to move greater distances along the agriculture border to reach their different feeding areas. For example, if the corridor between Masinagudi and Singara villages is cut off by agriculture or electric fencing (privately

TABLE 3

EVALUATION OF THE DIFFERENT ADMINISTRATIVE AREAS WITH REFERENCE TO WILDLIFE MANAGEMENT

	Protection priority (wildlife)	Management priority (wildlife)	Infrastructure for protection of wildlife	Legal status (for wildlife management)	Total (+ve) value
Bandipur (N.P.)	5	5	5	5	20
Mudumalai (W.S.)	5	5	5	4	19
Reserve Forests	3	3	2	3	11
Revenue Land (Forests)	0	0	0	1	1
Private Land (Forests)	0	0	0	1	1

Score: 0 = nil, 1 = very low, 2 = low, 3 = moderate, 4 = high, 5 = very high.

owned land), then clan LBF (which moves east) or clan HCF (which moves west through this corridor) will have to go right round Masinagudi village. They will come into greater conflict with man (the greater the agriculture border they have to traverse, the more will be the crop raiding). Similarly the loss of any of the other corridors mentioned in the results section will lead to an escalation of the man-elephant conflict.

The loss of areas outside the sanctuary will adversely affect the study population in two ways. Firstly, there will be the direct loss of a part of the home range. This would also mean that the study population will spend more time in protected areas, thus increasing the pressure on the vegetation. Secondly, elephants originally occupying the areas lost are likely to move into protected areas and further increase the pressure on the vegetation. Loss of areas could also increase crop raiding as elephants will continue to move into areas which were once a part of their range. The increased numbers within the park and the resultant competition will also force some elephants to turn to agricultural crops for their food.

The location and size of the study animals' home ranges point to several problems with regard to the management of elephants within protected areas. As the home ranges are spread over several different administrative areas, problems can arise with their administration. As can be seen from Table 2, the home range of most animals studied extends across two states (Tamil Nadu and Karnataka) and in one case even extends into Kerala (there are clans on the western part of Mudumalai W.S. which range well into Wynaad W.S., but these are not discussed here because they have not been studied in detail). In addition, all the home ranges, except clan RDC, come under three totally different administrative agencies, namely the Forest Department, Revenue Department and private land owners. Even the Forest Dept. has two sub-departments, Wildlife and Territorial. The Wildlife Dept. again has two different levels of protection, National Park and Wildlife Sanctuary. This means that the elephants and their habitat are constantly exposed to different levels of protection depending on the legal status of the area.

To evaluate these areas with reference to elephant management, the areas were graded on a scale from 0 (nil) to 5 (very high) and the total score was given as a positive score. The areas were scored for protection and management (whether wildlife is a priority), infrastructure and legal status (whether adequate for wildlife management and protection). Table 3 gives the scores for the different areas.

The maximum possible score is 20 and the objective of management should be to increase the scores of areas with low scores. Bandipur N.P. with the maximum score rates higher than Mudumalai with a score of 19, only because it has a higher legal status as a National Park. There is a proposal to upgrade a part of

TABLE 4

THREATS TO THE HABITAT OF THE STUDY POPULATION IN DIFFERENT ADMINISTRATIVE AREAS

Columns	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Possibility of being converted to non-forest use	Cattle grazing	Fuel wood	Enclosed villages and cattle pens	Potential to increase man-elephant conflict (if lost)	Detrimental* impact on the protected elephant population (if lost)	Total (– ve) value
Bandipur (N. P.)	0	1	2	0	N.A.	N.A.	3
Mudumalai (W. S)	0	3	3	3	N.A.	N.A.	9
Reserve Forests	1	5	5	4	5	5	25
Revenue Land (Forests)	4	5	5	5	5	4	28
Private Land (Forests)	5	4	2	0	5	4	20

N.A. = Not applicable, = Protected population in this case applies to the elephants within Mudumalai W.S.

Mudumalai W.S. into a National Park. This will increase funds available to the Sanctuary (for improvement of infrastructure) but since Mudumalai W.S. has already scored the maximum 5 points in this category, no real improvement will result unless the improved legal status is used to solve the problems shown in Table 4. The areas that really need attention are the Reserve Forests, Revenue Lands (forests) and Private Forests. It is here that significant improvement can be made.

The most important point to remember about the information contained in Table 3 is that it does not show how good an area is, but rather tells the managers of Bandipur N.P. and Mudumalai W.S. where the real danger lies to a part of their elephant population. Bad management in any part of the home range will affect all the areas, irrespective of how well the other areas are managed. A typical example would be the case of the adult male CT. CT, a good breeding bull, was shot in the Reserve Forest area well outside Mudumalai W.S. It has resulted in the loss of a very good breeding bull to both Mudumalai W.S. and Bandipur N.P. Similarly, any degradation or loss of habitat or corridors in any of the areas will adversely affect the study population.

Threats in different administrative areas were also evaluated. A 0 (nil) to 5 (very high) scoring was done for different categories. Here the scoring is negative and the objective of the managers in this case would be to reduce the score as low as possible, 0 being the best (not necessarily impossible). Table 4 gives the scores for different areas.

The threat of habitat loss (column 1 of Table 4) is very real in the near future if no action is taken. This is specially true in the case of Revenue Lands. Those under private ownership are likely to be lost to elephants as soon as the owners decide to make use of that land for agriculture or even decide to fence it off using electric fences. The lands under the Revenue Dept. are also likely to be used for agriculture some time in the future, and they are also exposed to encroachment (illegal occupation). The Reserve Forests are fairly safe, but development in the long run may put a lot of pressure on them. A Sanctuary or National Park status can make them much more secure. Some basic questions that have to be looked into are the economic aspects:

(1) the revenue the area generates at present and whether it is really so high that the area cannot be converted into a Sanctuary,

foregoing the revenue, and (2) what added benefits Sanctuary/N.P. status will bring, like better protection and even revenue in the form of tourism.

In addition to the loss of habitat, the threat of habitat degradation in the form of cattle grazing, firewood collection and villages/cattle pens within the forests has also been evaluated (Table 4). Both cattle grazing and firewood collection can degrade the habitat, making it unsuitable for elephants in the long run if left unchecked. Similarly villages and cattle pens within the forests effectively deny the use of certain areas to elephants.

Columns 5 and 6 of Table 4 have been scored as not applicable to Sanctuaries and National Parks, as it has been assumed that these areas will not be lost to elephants. In all the other cases these columns contribute greatly to the negative score. With reference to elephant management a dual problem is being faced, namely protecting the elephant and its habitat and the reduction of man-elephant conflict.

From column 7 of Table 4 the areas that are most threatened can be identified, and by looking at columns 5 and 6 the severity of loss in terms of adverse impact on elephants and in terms of increased man-elephant conflict can be gauged. From columns 1 to 4 the source and magnitude of the problem can be assessed.

Converting the Revenue and private forests to Sanctuary status will remove the threat of loss. But the problems of degradation (cattle, settlements, etc.) will continue to pose a serious threat. This threat is also faced by the Reserve Forests. Any further upgrading of status is useful only if it can reduce these problems. Management objectives and actions should be towards solving these problems.

Conclusions

This paper has attempted to highlight the management issues raised by the study of home range of elephants in and around Mudumalai W.S. The findings are also relevant to the design and management of other elephant areas. Some of the critical problems and recommendations that are identified by this study are given below.

1. The boundaries of sanctuaries and other protected areas follow administrative boundaries. These rarely take into account the home ranges of animals, mainly because such information is not available for most areas which are to be protected. This flaw in design should be corrected as and when the necessary information becomes available.

2. For conservation purposes a population should be considered to be living in a protected area only if its entire home range comes under the protected area (e.g. female RDC, whose entire home range lies within the protected areas of Mudumalai and Bandipur (Fig. 2). In case of populations which range outside the protected area as part of their normal seasonal movement, the protected area should be extended to cover the entire range, or these should not be treated as living in protected areas (e.g. clans LBF and RDC, and males RSB and TPSR).

3. The absence of accurate information on ranging behaviour is definitely a drawback for designing and managing elephant areas. Studies on ranging behaviour should be taken up. Radio telemetry is by far the best and the most accurate means of studying ranging behaviour.

4. The villages like Masinagudi, Moyar, Singara, Mavinhalla, etc. are growing rapidly and will put a lot of pressure on the surrounding forests. If action is not taken to stop habitat degradation and loss soon, most of the corridors and feeding areas around these villages will be lost. This will lead to severe man-elephant conflict.

5. The areas mentioned as corridors are very critical to maintain the man-elephant conflict at its present low level. Any loss of these corridors will lead to an escalation of this con-

flict. It will also have a negative impact on one of the most viable elephant populations in Asia. The key corridors are:

(a) Between Masinagudi and Moyar villages; here the canal cuts right across the path. At present elephants can cross it easily. Any modification to the canal should have facilities to allow elephants (and other wildlife) to cross the canal at several points.

(b) The strip of forested land between Masinagudi and Singara village (owned by the Singara Estate) should be acquired by the Forest Department.

(c) Revenue Land (forested) which act as corridors are:

(i) Between Singara R.F. and Kalhatti Slopes R.F. and to the north of Bokkapuram.

(ii) Between Mavinhalla and Chadapatti villages.

(iii) Between Mavinhalla and Chemmanattam villages. These revenue lands should also be acquired by the Forest Department.

(d) Reserve Forests which act as corridors are Singara R.F., Kalhatti Slopes R.F. and Sigur R.F., Sigur being the most important.

The Sigur and Singara Ranges along with Mudumalai W.S. are part of a single ecosystem which forms a vital part of the elephants' range in the Western Ghats. It would be very useful to convert these areas into a sanctuary, especially taking into account the limited revenues they now generate.

6. Departmental (Forest) development within the elephants' range should take into account the requirements of elephants. Fencing (electric) for habitat improvement should be done only in areas where it will not deny elephants access to critical areas or hamper normal seasonal movement. Barbed wire or chain-link fencing should not be erected in areas of regular elephant use or paths as these will be pulled down by the elephants, resulting in the loss of scarce resources (money) and at the same time serving no purpose, as cattle can get in once elephants break the fence.

Today even the protected areas are under considerable pressure, so the revenue and private forests will be lost sooner or later if they cannot be brought under protection soon. Their loss will not only lead to a severe increase in the man-elephant conflict, but will also have an adverse impact on one of the best elephant populations in Asia.

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